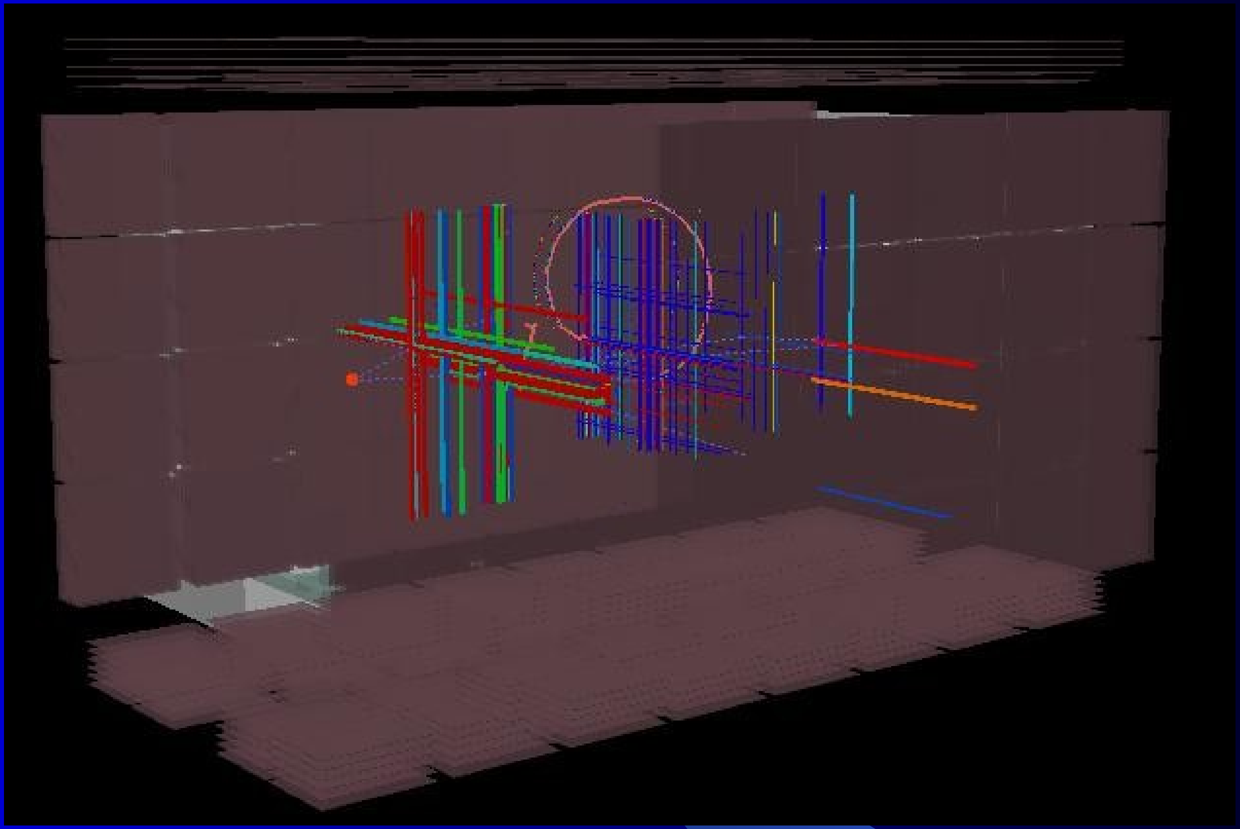

THE P0D – MEASURING π^0's AT THE NEAR DETECTOR OF T2K

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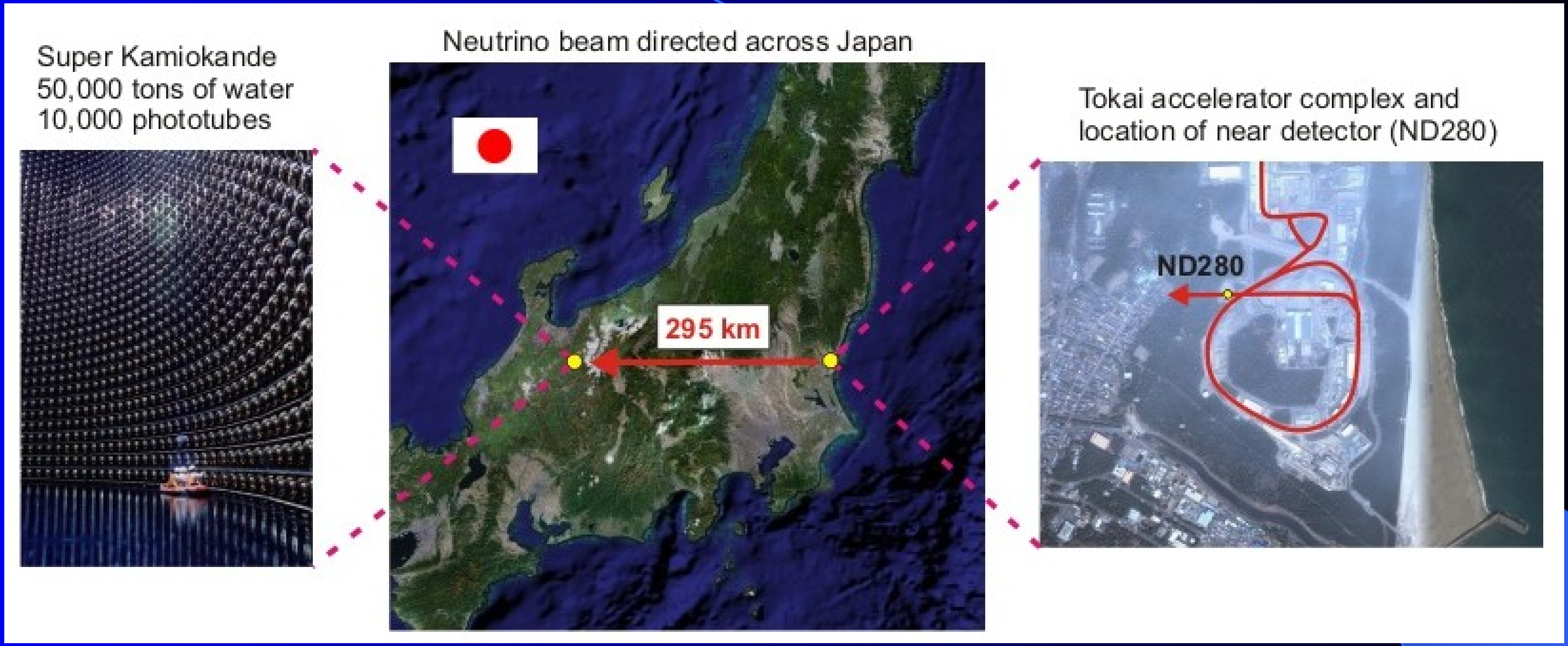
The T2K Experiment



- Long beamline neutrino experiment
- Generate ν ’s in Tokai at the 50 GeV JPARC facility and then send 295 km to Super Kamiokande for observation.
- Intended for improved measurements of mixing parameters such as θ_{23}, Δm_{23}, θ_{13}, Δm_{13}, and possibly δ in future upgrades.

Neutrino Oscillation

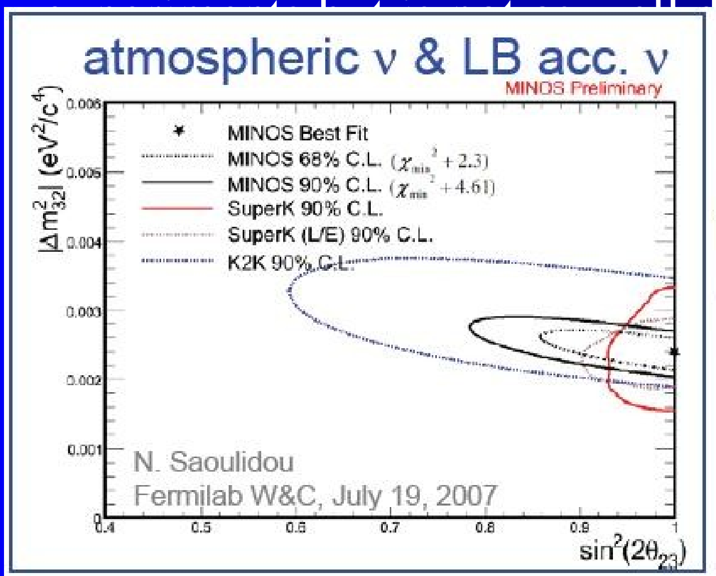
$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & Cos\theta_{23} & Sin\theta_{23} \\ 0 & -Sin\theta_{23} & Cos\theta_{23} \end{pmatrix} \begin{pmatrix} Cos\theta_{13} & 0 & Sin\theta_{13}e^{i\delta} \\ 0 & 1 & 0 \\ -Sin\theta_{13}e^{-i\delta} & 0 & Cos\theta_{13} \end{pmatrix} \begin{pmatrix} Cos\theta_{12} & Sin\theta_{12} & 0 \\ -Sin\theta_{12} & Cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

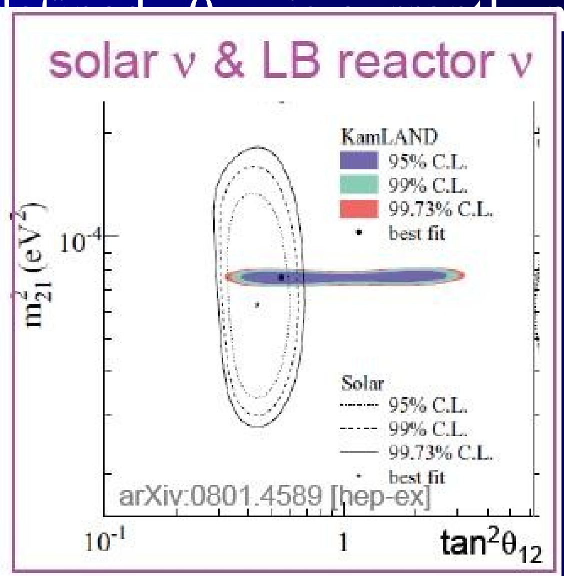
∀ν 's mass eigenstates are not the same as the flavor eigenstates.

•Can represent the oscillation between flavor as a 3-D rotation in a 3-D in mass space.

∀θ_{12} is well known from solar ν experiments. θ_{23} is known from atmosphere ν

ot well known.





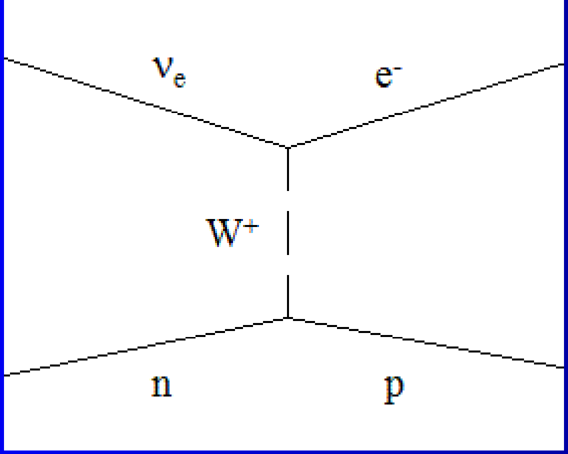
•Knowledge of θ_{13} is useful for completeness but is also important in determining δ .

Measuring θ 13 at T2K

To first order, θ_{13} can be found by looking for ν_e appearance in a beam of ν_μ.

$$P(\nu_\mu \rightarrow \nu_e) \approx sin^2 2\theta_{13} sin^2 2\theta_{23} sin^2(\Delta m^2_{13} L/4E)$$

The ν_e can be found a Super Kamiokande via a charged current interaction

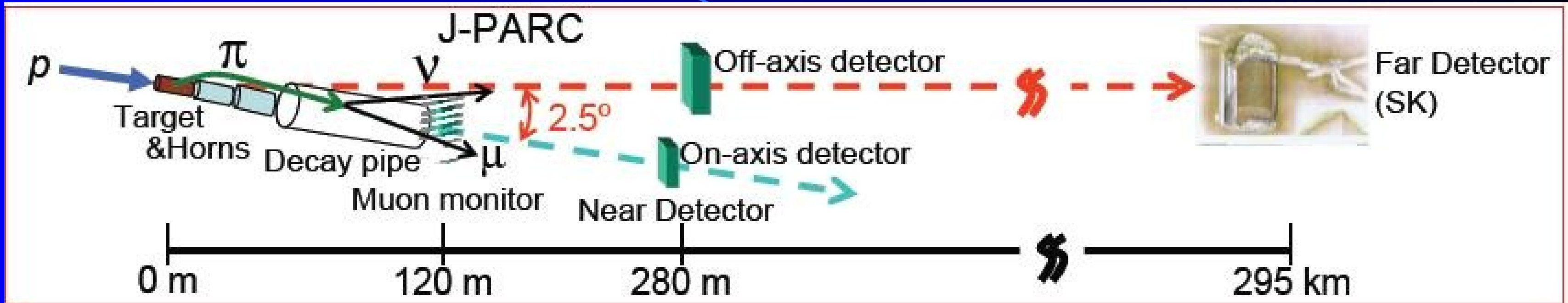


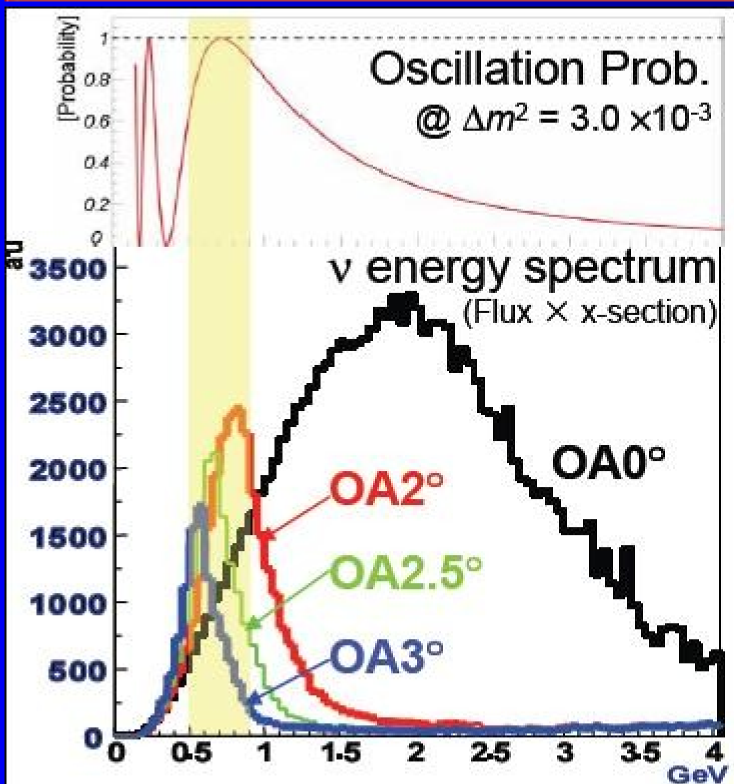
Misidentified π^0 from NC ν_μ reaction could produce background. An additional background could be ν_e contamination coming from the beam source.

Expected number of events at SK (0.75kW beam x 5yr)

$sin^2 2\theta_{13}$	Backgrounds			Signal
	ν_μ induced	Beam ν_e	Total	
0.1	10	13	23	103
0.01				10

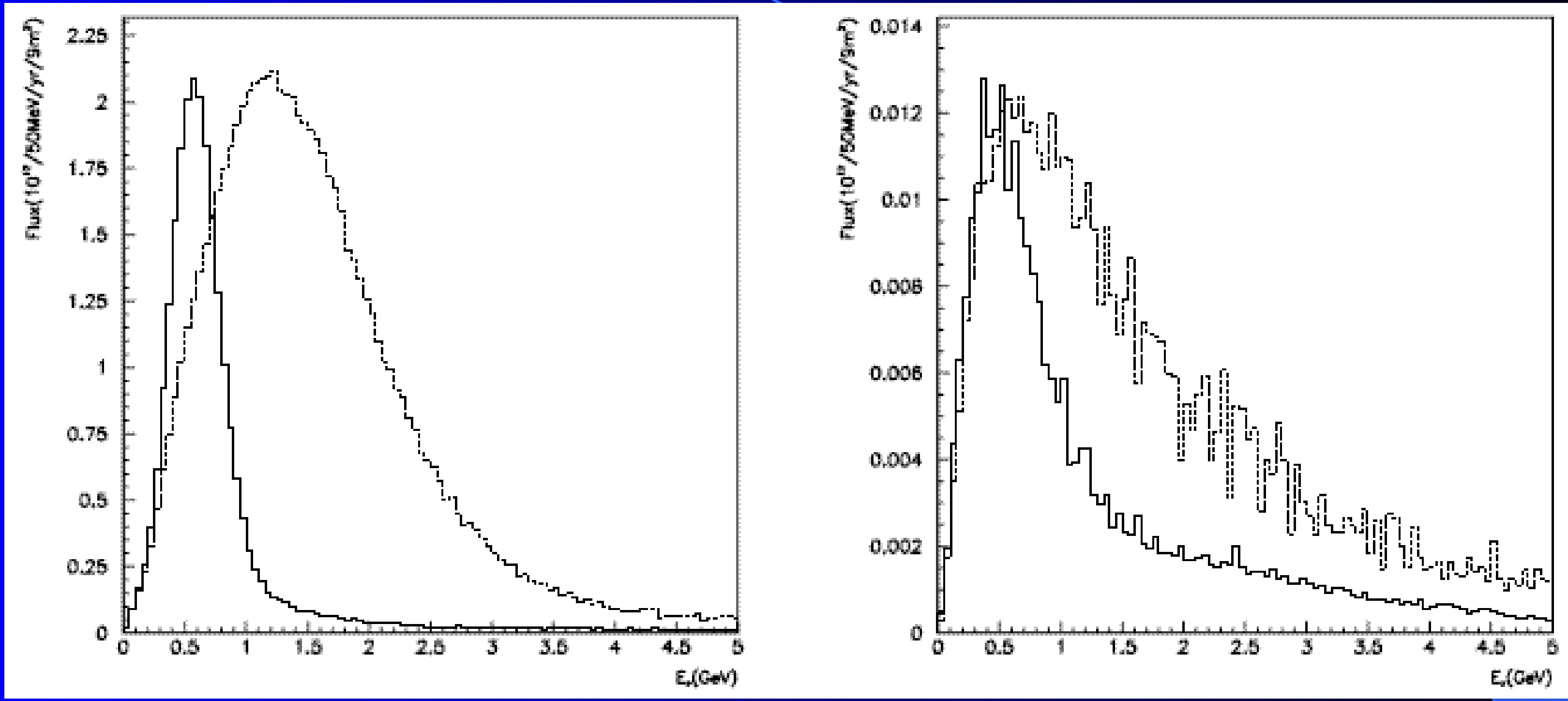
Off-Axis Measurement





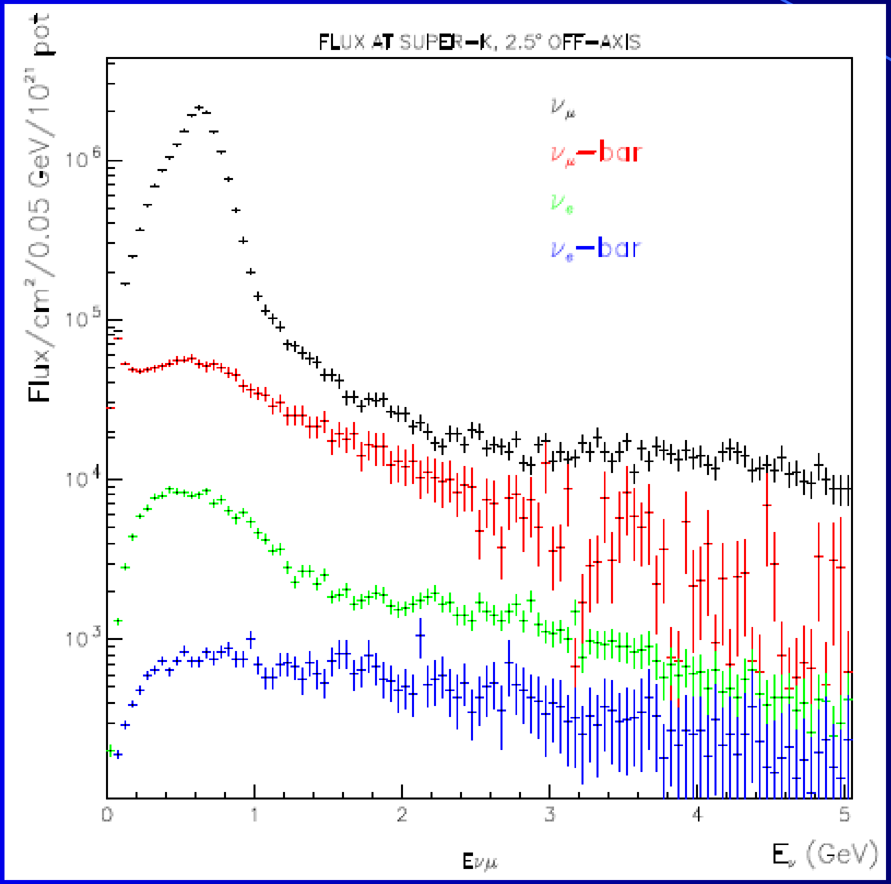
- Look at ν which are slightly off the beamline axis. Gives a tighter energy distribution which will allow for a maximum oscillation at the Far Detector.

Beam ν_e contamination



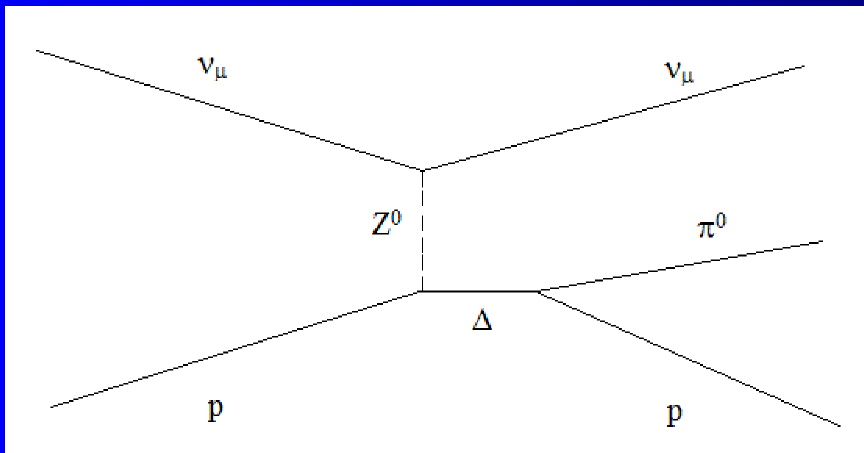
Left is ν_μ and the right is ν_e production. Dashed line represents on-axis while the solid line represents off-axis (2.5 degrees). Possible to reduce somewhat by energy cuts. At the ν_μ peak, the ν_e flux is about 0.4%.

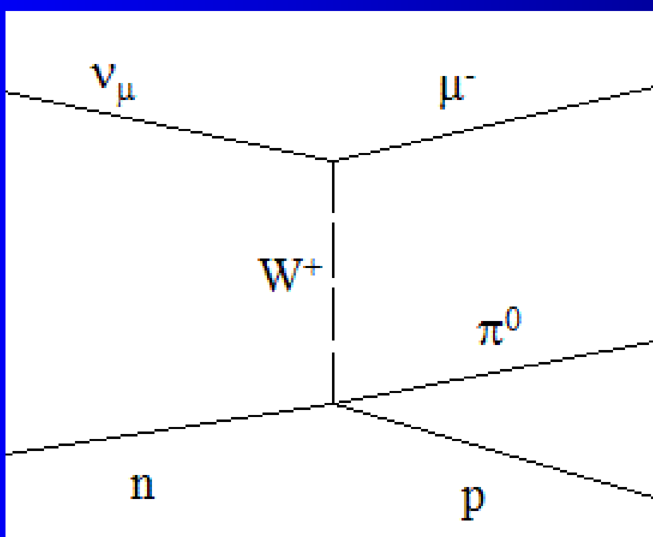
Beam ν_e contamination (cont.)



Black is ν_μ, red is ν_μ-bar, green is ν_e, and blue is ν_e-bar. The ν_e production comes mostly from μ decay as well as from kaon decay (K_L and K^+). The ν_e from kaon decay is mostly uniform in energy (3-body decay), while from μ is mostly at lower energy.

π^0 Background

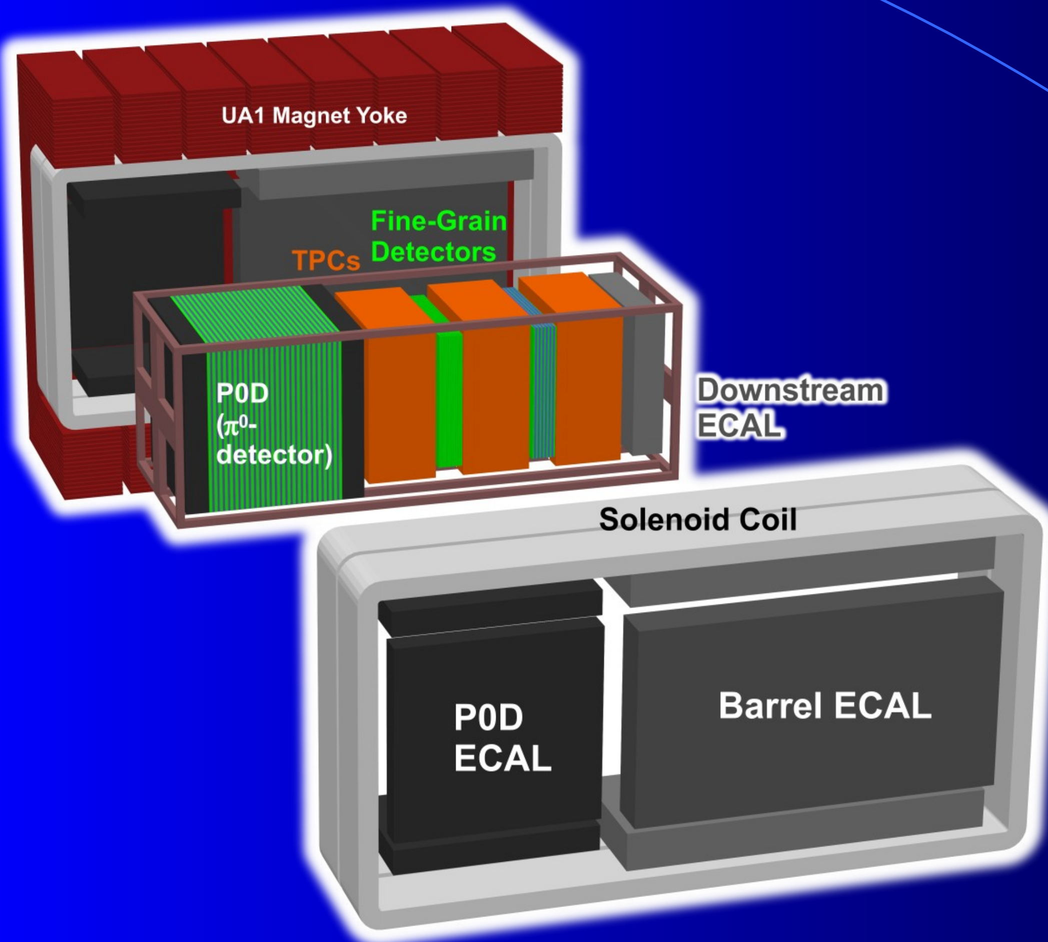




∀π^0's can come from NC or CC reactions.

- CC accompanied by muon that can be identified.
- NC π^0 may be misidentified as an electron if an electron from one photon is seen and the other is misidentified or lost.
- Need to better understand the cross section for this interaction in order to reduce background.

The Near Detector of T2K



Purpose of the Near Detector:

- Measurement of ν flux,
- Measurement of ν energy spectrum for estimation for a "near/far" ratio,
- Measurement of ν cross section for background (and just interesting physics),
- Measurement of ν_e contamination from the beam,
- Measuring and monitoring of ν beam (on-axis detector).
- Due to high flux, a water Cherenkov detector will not be used.

Measuring the π^0 Cross Section

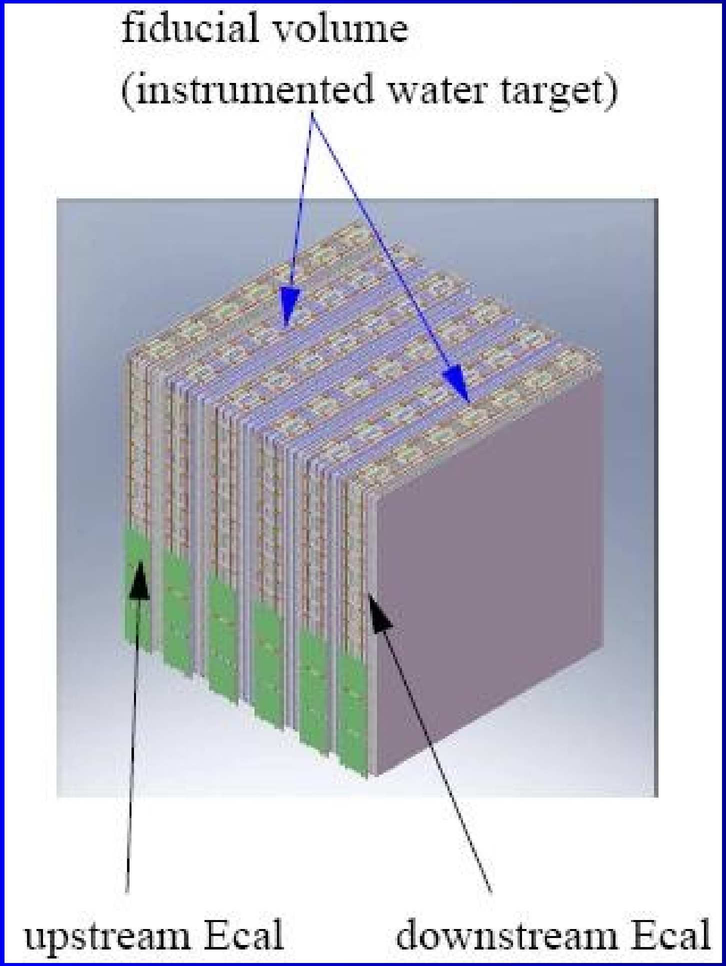
$$N_{scattered} = \sigma \Phi_{incoming} n_{targets}$$

- Need to known the incoming flux to find the cross section. (absolute measurement)
- Instead, find a relative measurement. Measure σ_{CCQE} compared to σ_{π}.

∀ σ_{CCQE} can be calculated fairly easily from theory and can be more easily measured.

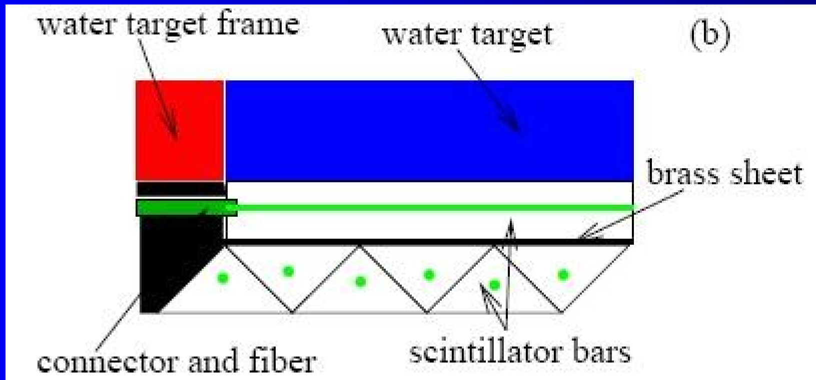
- Relative measurement allows for removal of common systematic errors, but will induce other errors. Important to have a well understood reference.

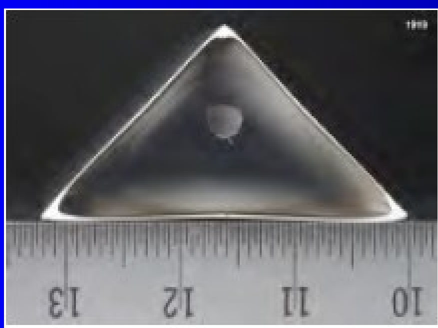
The π^0 Detector (P0D)



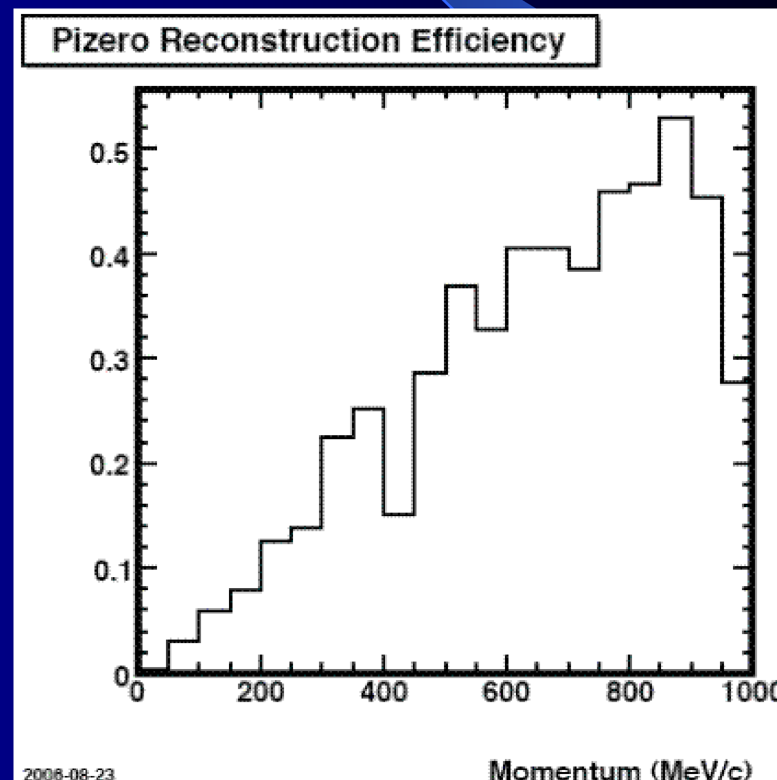
- Middle section contains water targets while the ends are upstream and downstream calorimeters with lead for targets. Can be used for veto.
- Will run with and without water to find the O_2 interaction cross section to represent NC events at Super Kamiokande.
- Plastic scintillator with brass foil to enhance production of electrons/positrons from photons from π^0 decay.
- Surrounded by the calorimeter for additional measurement of photons although the portion surrounding the P0D is not accurate enough for reconstruction. Also used for veto.

The π^0 Detector (P0D) (cont.)

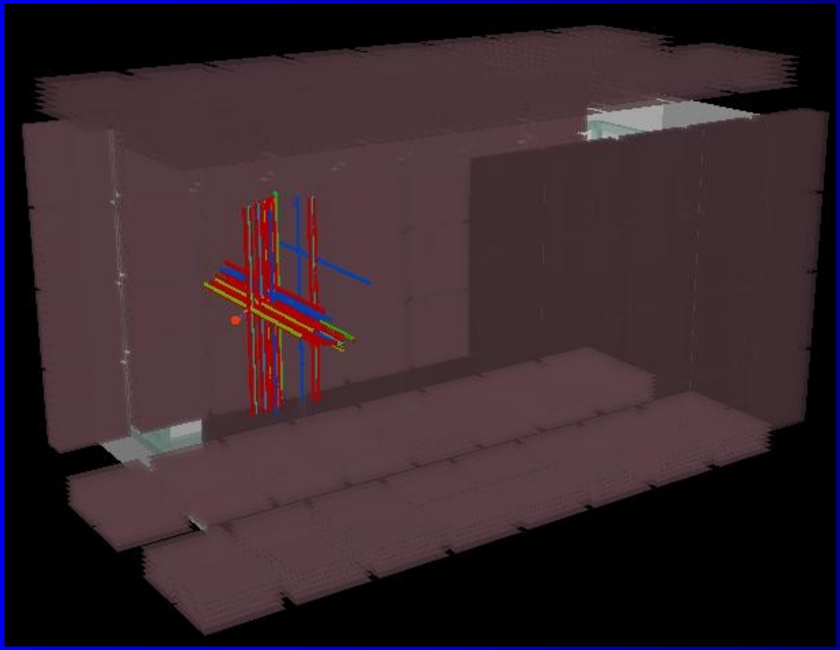


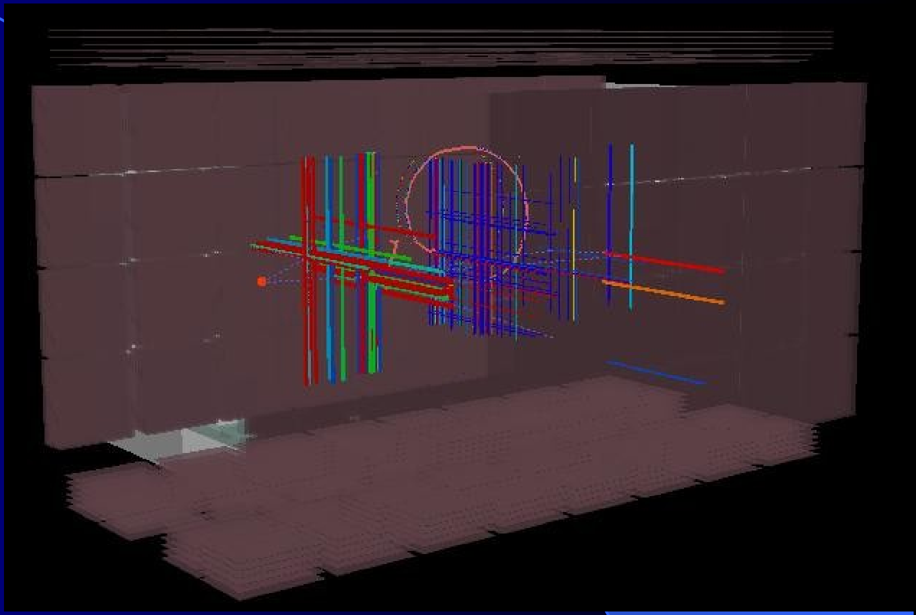


- Energy resolution for a fully contained event should be about 10% + 3.5%/(GeV)$^{1/2}$ and the average efficiency to reconstruct a π^0 with p≥ 200 MeV is about 33%.



The π^0 Detector (P0D) (cont.)





Most low energy events will be contained in the P0D while some higher energy events may escape into other elements of the detector.

Conclusions

- Look for θ_{13} by looking for ν_e appearance.
- Need to understand backgrounds.

∀ν_e contamination from beam. Can partially reduce by energy cuts.

- Misidentified π^0 at Super Kamiokande may appear to be electrons from ν_e.
- P0D will be used to study the NCπ^0 reaction in order to determine the cross section.
- Study will allow a limit to be set on that background.

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